Martian Maneuvers (Part 1 of 3):

[Adapted from Lunar Lander Activities, NASA]

What is it?

Scientists and Engineers are curious about all of the planets in our Solar System, but they are particularly curious about Mars. In August of 2012, the Mars Science Laboratory: Curiosity, landed on the Martian surface. In these three activities, students will learn about the different challenges faced by scientists and engineers when trying to land a rover. They will also learn about the most recent rover to Mars.

In order to learn more about Mars, NASA continues to send robotic missions to gather information about this distant world. As part of this, engineers need to be sure that their scientific instruments land safely on the surface.

In this first part, students will construct a transport rover. The rover will need to be able to carry goods (plastic egg) down a ramp to the Martian Surface.

This activity discusses topics related to National Science Education Standards:

MS-ETS1-1: *Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.*

- Students enter into a design challenge activity, where the constraints are clearly defined, and the environment is limited by mission and resources.

Materials (per team of 4 to 8 students):

Equipment, provided by NASA:

- Plastic Egg
- Wooden Wheels (4)

Consumables, not provided by NASA:

- Building Supplies (straws, dowels, foam, egg carton segments, paper cups, cardboard, newspaper, string, rubber bands, tape, paper clips, etc.)
- *Optional: if you would like to make this activity more of a challenge, replace the wooden wheels with other round items, like CDs, bottle caps, etc.*

Printables:

- Rover Image and Plan Worksheet
- Rover Re-Design and Re-Build Worksheet

Materials (for entire class)
Equipment, provided by NASA:

- Ramp

Artifact included in this kit:

- NASA's Mars Rover Curiosity Artifact Kit which includes:
    - *Artifact Kit*: Samples of the actual Multi-Layer Insulation, Pyromechanisms, and Bridle used on the mission.
    - *Mars Rocks!* Flash Cards: information about the mission artifacts

Recommended Speakers from Ames:
Please note that our Speakers Bureau program is voluntary and we cannot guarantee the availability of any speaker. To request a speaker, please visit http://speakers.grc.nasa.gov.

Mark Leon (Lunar Micro Rover project)

Guy Pyrzak (Computer software, Mars Lander and Rover Planning and Problem, Hazard and Saftey Reporting)

Brian Glass (robotics, geology and geophysics, drilling on Mars)

Set-Up Recommendations:

- Lay out all of the building materials at the front of the room
- Lay out connecting materials (scissors, tape, glue, etc.) for each team
- Prepare copies of the **Rover Imagine and Plan Worksheet** and **Rover Re-Design and Re-Build Worksheet** for each team
- Write the "Design Requirements" (listed below) on the board at the front of the room or prepare copies of the Design Requirements for each team.

Procedure:

1. Share the challenge with students. We suggest writing the following requirements on the board at the front of the room. Students will have one class period to design and build a Mars Rover. Their rover will need to meet the following requirements:
    a. Carry one plastic egg snugly. The egg may NOT be taped nor glued to your rover. It must be able to be removed after deployment.
    b. Roll on its own down the ramp provided.
    c. Survive the "deployment" (after rolling down the ramp, the plastic egg needs to stay intact).
    d. Keep in mind that your rover will need to survive an EDL (entry, descent, and landing) sequence in the future.
2. Break students into teams of 4 to 8 students. Each team can assign roles to students (project manager, quality control, chief engineer, data analysis, etc.) or

work together on all aspects of the project. Hand out the **Rover Imagine and Plan Worksheet** and give students 10 minutes to answer the questions with their teams.

3. After working through their worksheets, give students 5 minutes to write a "shopping list" on the back looking at the materials at the front of the room. The whole team needs to agree on the shopping list.
    a. *Optional Extension: Add a price value to each item and have students work within a budget.*

4. After they have decided what they need to build, have one member of each team come up to the front to gather up their materials.
5. **Build!** Now it's time for the students to build. Give students 20 minutes do build their rovers. Be sure to leave at least 20 minutes at the end of the class period for testing and improvement. Hand out the **Rover Re-Design and Re-Build Worksheet** to each team.
6. Begin testing the rovers. Each team will get three tries. During those tries, ask the teams to take notes on the back of their worksheets. They can answer the questions together after their tests.
    a. *Optional Extension: Have students measure the distance their rover rolls and take the mean, median and mode of the class data.*
    b. *Optional Extension: Turn this into a competition! The team whose rover rolls the furthest is the winner! Have teams compete with other class periods!*
7. With the last 10 minutes of class, allow students time to make improvements to their rovers from the notes they made on their worksheets.
8. If you have time left, retest the rovers. If not, they can be retested at the beginning of the next part of the challenge.

Helpful Resources:

About the NASA Mars Exploration Program:
http://mars.nasa.gov

About Mars:
http://www.nasa.gov/mission_pages/mars/main/index.html

Safety:

- Using scissors can cause cuts. Please practice scissor safety.
- Although most glues are non-toxic, please be sure that it is not consumed

Team Name: ____

Rover Imagine and Plan Worksheet

What do you need to make your rover roll?

What will hold the egg in place?

Top View of Rover:

Sketch of how you are going to build the wheel assembly:

Team Name: ____

Rover Re-Design and Re-Build Worksheet

How far did your rover roll for each trial?

How can you improve your design? Hint: is there a way to increase the speed of your rover?

Did your rover not roll at all? ☐ Yes ☐ No

If so, how can you improve your design? Hint: is there something wrong with your wheel assembly?

Did your egg stay intact in the rover? ☐ Yes ☐ No

If not, how can you improve your design? Hint: is there some secure way you can contain it without taping it to your rover?

Are their other design improvements needed? ☐ Yes ☐ No

How are you going to make these other improvements?

Martian Maneuvers (Part 2 of 3):

[Adapted from Lunar Lander Activities, NASA]

What is it?

Scientists and Engineers are curious about all of the planets in our Solar System, but they are particularly curious about Mars. In August of 2012, the Mars Science Laboratory: Curiosity, landed on the Martian surface. In these three activities, students will learn about the different challenges faced by scientists and engineers when trying to land a rover. They will also learn about the most recent rover to Mars.

Maneuvering on the surface is one thing, but getting down to the surface is entirely another. The distance between Earth and Mars is about 3.4 million miles and it takes a signal about 14 minutes to travel between the two. This means that the engineering needed to successfully complete the Entry, Descent, and Landing (EDL) stage of a rover is as critical as the engineering that goes into designing the payload. In this second part, the teams will design and build a EDL stage for their rover.

This activity discusses topics related to National Science Education Standards:

MS-ETS1-1: *Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.*

- Students enter into a design challenge activity, where the constraints are clearly defined, and the environment is limited by mission and resources.

Materials (per team of 4 to 8 students):

Equipment, not provided by NASA:

- The Team Rover (built in Part 1)

Consumables, not provided by NASA:

- Building Supplies (straws, dowels, foam, egg carton segments, paper cups, cardboard, newspaper, string, rubber bands, tape, paper clips, etc.), including bubble wrap and manila folders

Printables:

- EDL Image and Plan Worksheet
- EDL Re-Design and Re-Build Worksheet

Materials (for entire class)

Equipment, not provided by NASA:

- Computer with access to the internet
- Measuring device (either a meter stick, piece of paper taped to the wall, etc.)

Equipment, provided by NASA:

- “Curiosity’s Seven Minutes of Terror” video: http://www.nasa.gov/multimedia/videogallery/index.html?media_id=146903741

Artifact included in this kit:

- NASA’s Mars Rover Curiosity Kit which includes:
    - *Rock and Mineral Kit*: Rocks and minerals the rover is looking for in Gale Crater.
    - *Artifact Kit*: Samples of the actual Multi-Layer Insulation, Pyromechanisms, and Bridle used on the mission.
    - *Mars Rocks!* Flash Cards: information about the mission artifacts

Recommended Speakers from Ames:

Please note that our Speakers Bureau program is voluntary and we cannot guarantee the availability of any speaker. To request a speaker, please visit http://speakers.grc.nasa.gov.

Mark Leon (Lunar Micro Rover project)

Guy Pyrzak (Computer software, Mars Lander and Rover Planning and Problem, Hazard and Saftey Reporting)

Brian Glass (robotics, geology and geophysics, drilling on Mars)

Set-Up Recommendations:

- Lay out all of the building materials at the front of the room
- Lay out connecting materials (scissors, tape, glue, etc.) for each team
- Prepare copies of the **EDL Imagine and Plan Worksheet** and **EDL Re-Design and Re-Build Worksheet** for each team
- Set up computer with screen/projector/etc. to show “Curiosity’s Seven Minutes of Terror”
- Write the “Design Requirements” (listed below in the procedure section) on the board at the front of the room or prepare copies of the Design Requirements for each team.

Possible Modification:

If you are not planning on conducting Part 1 with your class, you can still conduct this lesson using a prepared rover for each student to test with.

Procedure:

1. Share the challenge with students. We suggest writing the following requirements on the board at the front of the room. Students will have one class period to design and build an Entry, Descent and Landing (EDL) stage (or Landing Pod) for their rovers. Their EDL stage will need to meet the following requirements
    a. The EDL stage must deliver the rover to the surface from the lowest designated height required (aka, be dropped from a minimum height designated by the teacher; we recommend at least 1.5 meters).
    b. The rover, inside the EDL stage, must land RIGHT-SIDE-UP as it will need to be able to roll out.
    c. The EDL stage must be reusable. You must be able to open it, retrieve the rover, and then use the EDL stage again
2. Hand out the **EDL Imagine and Plan Worksheet** and give students 5 minutes to answer the questions with their teams.
3. After working through their worksheets, give students 5 minutes to write a "shopping list" on the back looking at the materials at the front of the room. The whole team needs to agree on the shopping list.
    a. *Optional Extension: Assign a value to each item and have students work within a budget.*
4. After they have decided what they need to build, have one member of each team come up to the front to gather up their materials.
    a. *Optional Extension: To create more of a challenge, the students can have a limited number of materials to build.*
5. **Build!** Now it's time for the students to build. Give students 20 minutes do build their EDL stages. They can of course come up for more materials, or to exchange materials they have. Be sure to leave at least 20 minutes at the end of the class period for testing and improvement. Hand out the **EDL Re-Design and Re-Build Worksheet** to each team.
6. Begin testing the EDL stages. Each team will get three tries. During those tries, ask the teams to take notes on the back of their worksheets. They can answer the questions together after their tests.
7. With the last 10 minutes of class, allow students time to make improvements to their EDL stages from the notes they made on their worksheets.
8. If you have time left, retest the EDL stages. If not, they can be retested at the beginning of the next part of the challenge.

Helpful Resources:

About the NASA Mars Exploration Program:
http://mars.nasa.gov

About the Curiosity Rover:
http://www.nasa.gov/msl
Safety:

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- Although most glues are non-toxic, please be sure that it is not consumed

Team Name: ____

EDL Imagine and Plan Worksheet

What does EDL stand for?

From how high will the rover have to land safely inside of your EDL stage?

How will you make sure that the rover lands right-side-up?

Top View of EDL Stage:

Side View of EDL Stage:

Sketch the “door” or “hatch” on your EDL stage:

Team Name: ____

EDL Re-Design and Re-Build Worksheet

Did the rover land right-side-up? ☐ Yes ☐ No

If not, how can you improve your design? Hint: is there a way to add weight to the EDL stage to get it to right itself during its fall?

Does your door easily open after landing? ☐ Yes ☐ No

If not, how can you improve your design? Hint: is there a better shape to use for your EDL stage?

What was the most difficult constraint to satisfy?

Are their other design improvements needed? ☐ Yes ☐ No

How are you going to make these other improvements?

Martian Maneuvers (Part 3 of 3):

[Adapted from Lunar Lander Activities, NASA]

What is it?

Scientists and Engineers are curious about all of the planets in our Solar System, but they are particularly curious about Mars. In August of 2012, the Mars Science Laboratory: Curiosity, landed on the Martian surface. In these three activities, students will learn about the different challenges faced by scientists and engineers when trying to land a rover. They will also learn about the most recent rover to Mars.

Students have come so far! They have designed their own rovers, and have designed the EDL stage to get it to the surface!

Now, it's time to put it all together and test their entire mission!

This activity discusses topics related to National Science Education Standards:

MS-ETS1-2: *Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem*

- Students will analyze the successfulness of their rover and EDL stage designs in relation to the constraints presented in the first two activities.

Materials (per team of 4 to 8 students):

Equipment, not provided by NASA:

- The Team Rover (built in Part 1) with plastic egg
- The Team EDL Stage (built in Part 2)

Consumables, not provided by NASA:

- Optional: Building Materials (straws, dowels, foam, egg carton segments, paper cups, cardboard, newspaper, string, rubber bands, tape, paper clips, etc.)

Printables:

- Martian Maneuvers Mission Worksheet

Materials (for entire class)

Equipment, not provided by NASA:

- Measuring device (either a meter stick, piece of paper taped to the wall, etc.)

Artifact included in this kit:

- NASA's Mars Rover Curiosity Artifact Kit which includes:
    - *Artifact Kit*: Samples of the actual Multi-Layer Insulation, Pyromechanisms, and Bridle used on the mission.

- *Mars Rocks!* Flash Cards: information about the mission artifacts

Recommended Speakers from Ames:
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Guy Pyrzak (Computer software, Mars Lander and Rover Planning and Problem, Hazard and Saftey Reporting)

Brian Glass (robotics, geology and geophysics, drilling on Mars)

Set-Up Recommendations:
- Lay out all of the building materials to the side of the room (Optional, if you wish to allow students to make improvements) along with connecting materials
- Prepare copies of the **Martian Maneuvers Mission Worksheet** for each team
- Write the "Design Requirements" (listed below in the procedure section) on the board at the front of the room or prepare copies of the Design Requirements for each team.

Possible Modification:
If you are not planning on conducting Part 1 or Part 2 with your class, you can still conduct this lesson using a prepared rover or EDL stage for each student to test with. We do recommend that students build either the rover or the EDL stage at least.

Procedure:

1. Finish up any outstanding steps from Part 2, if needed.
2. Share the schedule of events with students. We suggest writing the following requirements on the board at the front of the room. This class period, students will be testing their EDL stages and Rovers. Their mission must complete the following:
    a. The entire assembly (EDL stage and Rover) must be dropped from the teacher-specified height
    b. The EDL stage (with Rover inside) must land upright
    c. The door of the EDL Stage must be able to be opened so that the Rover can roll out.
    d. The plastic egg (Payload) must stay closed
3. Hand out the **Martian Maneuvers Mission Worksheet**
4. **<u>Test!</u>** It's time to test their assemblies! Each team will get three tries. Feel free to drop from higher heights as each team works through their three tries. As they are testing, have the team take notes on their worksheet. They can answer the questions at the end of class.

5. If you would like, allow students some time to make improvements to their designs and retest!
6. With the last 15 minutes of class, allow students time to answer the questions on their worksheets and share highlight moments with the class.
7. If you would like, assign **Martian Maneuvers Summary Worksheet** as homework for the students to reflect on their engineering experience!

Helpful Resources:

About Mars:
http://www.nasa.gov/mission_pages/mars/main/index.html

About the NASA Mars Exploration Program:
http://mars.nasa.gov

About the Curiosity Rover:
http://www.nasa.gov/msl

Safety:

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Team Name: ____

Martian Maneuvers Mission Worksheet

Trail	Height Dropped (m)	Distance Rolled (cm)
1		
2		
3		

Did your EDL stage remain closed during impact?

Did the EDL stage land so that your rover was upright inside?

Did your egg remain intact inside of your rover?

Did your rover roll out of the EDL stage?

How far did it roll?

Do you need to make changes to your assembly? If yes, what would they be?

Team Name: ____

Martian Maneuvers Summary

Consider the entire project: designing and building the Rover, designing and building the EDL stage, and actually launching the EDL stage with the Rover inside. What was the most challenging aspect of this process?

Did you think about the whole process when you were designing the Rover? Did you worry about how it would survive the landing as you were building it, or did you not think about that until you were building the EDL stage?

If you were to start this project again, would you change the design of the Rover? If so, how?

Would you change the design of the EDL stage? If so, how?